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RESEARCH ARTICLE

EVALUATION OF WATER QUALITY OF LOCAL STREAMS AND BAITARANI RIVER IN JODA AREA OF ODISHA, INDIA

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ABSTRACT

Levels of various physico-chemical parameters along with coliform cell units were determined for thirteen water samples in pre-monsoon, monsoon and post- monsoon periods between March-2011 to Feb-2012 to assess the water quality of three local streams and Baitarani river in Joda area of Keonjhar district. Most of the parameters were of maximum value in post-monsoon period. The samples were acidic in post-monsoon period where as slightly acidic to alkaline in other periods. The pH, EC, TDS, TH, the major cations and anions in all samples and DO values in most of the samples were well within the BIS and WHO limits. But turbidity, TSS, total and faecal coliform units and in some cases BOD values were beyond the limits indicating contaminated water bodies. Fe and Cr contributed a lot for high value of WQI. WQI value ranged from 96 to 359 infers poor to very poor quality of water and the sample from Dalko Nala(S8) was found to be unsuitable for drinking and bathing purpose. The overall water quality assessment indicates proper treatment of river/stream water for public consumption. The possible sources of contamination are weathering of rocks, soil erosion, extensive mining operations and anthropogenic activities. TDS, SAR, Na%, RSC values indicated good quality of water samples for irrigation.

INTRODUCTION

River basins are highly vulnerable to contamination due to absorption and transportation of domestic, industrial and agricultural waste water. Anthropogenic influence as well as natural processes degrade surface waters and impair their use for drinking, industrial, agricultural and recreational purposes (Kumar and Dua, 2009). India is heading towards a fresh water crisis mainly due to improper management of water resources and environmental degradation. Hence various technologies and policies to ensure the safety of this valuable resource is the need of the hour for a developing country like India. According to WHO organization, about 80% of all the diseases in human beings are water borne. The presence of various toxic substances in the water bodies causes health hazards. In addition to various physico-chemical parameters, the microbiological quality of water is important for environmental health because of its relationship to disease transmission. It therefore becomes imperative to regularly monitor the water quality of various sources to devise ways and means for its protection and to prevent occurrence of health hazards (Das *et al.,* 2012), (Reza and Singh, 2010). WQI (Water quality index) is one of the most effective tools to communicate information on overall quality status of water to the concerned user community and policy makers to shape sound public policy and implement the water quality improvement programmes efficiently (Tiwari and Mishra,1985), Kalavathy *et al.,* 2011) and can assess a stream/river's ability to host life and whether the overall quality of water bodies poses a potential threat to various uses of water (Kumar and Dua, 2009). Joda area is a part of Baitarani river basin of Keonjhar district of Odisha, rich in mineral resources with vast deposits of iron and manganese ores. Therefore, extensive mining and industrial activities leads to degradation of water quality of various water resources, particularly the local streams in the area. The area is mainly dominated by tribal population. Majority of them are mine workers and below poverty line with high level of illiteracy. Somany non-residents belonging to other districts and states reside in this area forming temporary slums. They are exclusively labourers working in various mines and industries. About 1 lakh people within the study area depend upon the local streams and Baitarani river directly and indirectly for various uses. No such extensive studies on water quality have been done so far in this area to highlight the extent of contamination and its impacts on the locality. Thus, most of the people of this area lack knowledge and awareness regarding water quality, contamination and its consequences. The purpose of the present study is to assess the water quality for drinking and irrigation use of the local streams like Jalpa Nadi, Balda Nala, Dalko Nala

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and Baitarani river flowing in Joda area using WQI along with some irrigational quality parameters, following Indian standard drinking water specification, IS 10500 : 2012.

Study area

The study area under investigation, in and around Joda is the north-west part of Keonjhar district of Odisha, bounded by latitude $21^0$50’30” and $22^0$03’06’’ north and longitude 85^0 23’48” and $85^0$32’52” east (Fig.1). It comprises of some part of Joda block and Joda Municipality that refers to the Topo sheet No.73F/8, 73F/12, 73G/5 and 73G/9.

The study area forms a part of Singhbhum-Keonjhar- Bonai Iron Ore Formation, belonging to Iron Ore Super Group of Pre-cambrian age. The major rock types of this area belong to Banded Iron formation such as BHJ, BHQ, BHC and banded–ferruginous shale. The BIF along with the volcanic, sedimentary and meta sedimentary rocks constitute the Iron Ore group. Other associated rocks are basic rocks and laterites such as sandstone and quartzite belong to Kolhan Group. The Basalt, Tuff, Metagabbro, Shale, Singhbhum Granite/ Hornblende Granite, Pellitic Schist and Amphibolites.

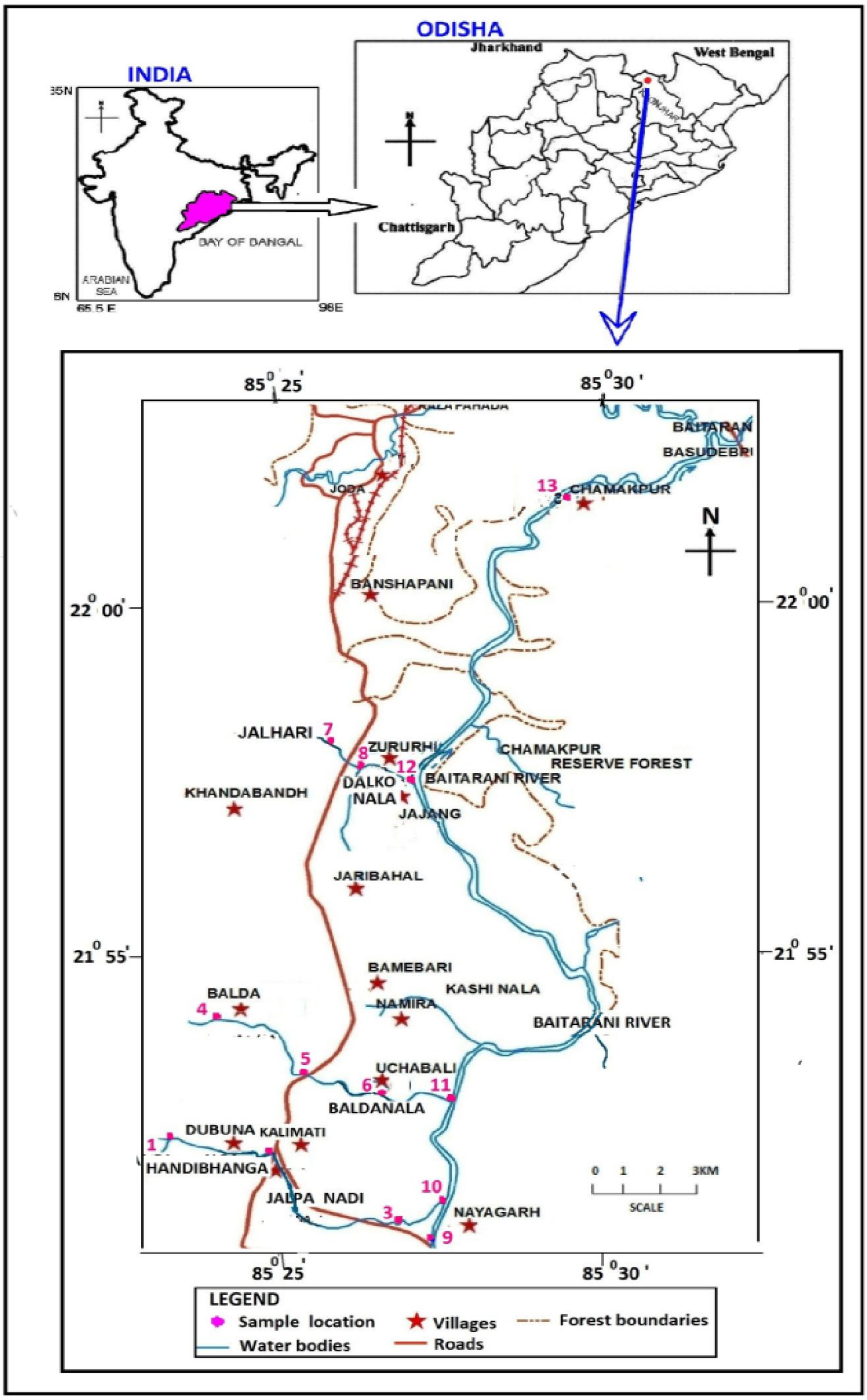

Fig.1. Map with sample locations in Joda area of Keonjar district

The major mineral deposits are haematite (Iron ore), pyrolusite and psilomilane (Manganese ore) and are associated with Iron Ore group of rocks. There are also some Precambrian limestone deposits in Joda. The surface of some places is occupied with light-textured laterites and medium- textured red loam soils. The average minimum and maximum temperature of this region is 8.9^0C and 40.6^0 C respectively with average rain fall of 1487 mm for last five years.

MATERIALS AND METHODS

The present study was carried out for a period of one year 2011-12. Water samples were collected from 13 different places from local streams and Baitarani river (Table 1) in pre-monsoon (March-June-2011), monsoon (July-October-2011) and post monsoon (November-February-2012) periods at a regular interval of once in a month. Water samples were collected in acid- washed plastic bottles of one l tr. capacity having double stopper facilities to its full capacity without entrapping air bubbles inside. Two bottles of water was collected from each station i.e. one for analysis of physico-chemical parameters and other for heavy metals. About two ml. of concentrated HNO_3 was added to the second bottle of each station to preserve the heavy metals present in the sample. Also, water Samples were collected in sterile glass bottles and were preserved in an ice bucket at 4^0C for analysis of total coliforms and faecal coliforms.

Table 1. Water sampling locations

Sample No.	Sample locations
S1	Jalapa Nadi at Handibhanga
S2	Jalapa Nadi at Kalimati
S3	Jalapa Nadi at Nayagarh
S4	Balda Nala at Balada
S5	Balda Nala, at Sirajudin B-Plot
S6	Balda Nala at Uchabali
S7	Dalko Nala, Upstream at Jalhari
S8	Dalko Nala at Zururhi
S9	Baitarani River at Nayagarh
S10	Confluence of Jalapa Nadi and Baitarani River
S11	Confluence of Balda Nala and Baitarani River
S12	Confluence of Dalko Nala and Baitarani River
S13	Baitarani River at Chamakpur

The collected samples were sent to water quality laboratory of Central Water Commission, Bhubaneswar for analysis of physico-chemical parameters like pH, turbidity, EC, TDS, TSS, total hardness, cations like Ca^{2+},Mg^{2+},Na^+,K^+, and anions like,HCO_3^-, SO_4^{2-}, NO_3^-, PO_4^{3-},Cl^-. Analysis of heavy metals like Fe and Cr were done by AAS (Shimadzu AA6300) and ICP-OES (PerkinElmer Optima 2100 DV) in IMMT, Bhubaneswar. However, pH, EC, were measured by using respective digital meters. Other parameters were measured by standard methodology of APHA (1998), (Trivedy and Goel, 1984). These parameters were compared with the standard guideline values, recomended by BIS-10500 (2012) and WHO (2006). WQI (Water quality index) was calculated (Kalavathy *et al.,* 2011), (Reza and Singh, 2005), (Mukherjee *et al*., 2012), (Ravikumar *et al*., 2013) for pre-monsoon, monsoon and post-monsoon periods to assess the suitability of water for drinking purposes and for biotic communities. For WQI calculation, total 14 parameters such as pH, turbidity, dissolved oxygen(DO), biological oxygen demand (BOD), total dissolved solids(TDS), total suspended solid (TSS), total hardness (TH), calcium (Ca) ions, magnesium (Mg) ions, total Fe, Cr, Cl^-, SO_4^{2-} , NO_3^- were considered and desirable limit of each parameter was used as per BIS standard. WQI was calculated from the following equation as per the details of water quality standard values and weightage factors (Table 3), which Involves the Following Steps:

First, the calculation of weightage of each parameter. Second, the calculation of the quality rating for each parameter. Third, the calculation of sub indices and then, summation of these sub-indices of all parameters to get the overall index.

Table 2. Water quality parameters with BIS standards and unit weights

PARAMETERS	BIS STANDARDS	WEIGHTAGE (Wi)
pH	6.5-8.5	0.0054
Turbidity	5	0.00814
TDS	500	0.0000814
TSS	100	0.00029
DO	6	0.0068
BOD	3	0.0136
TH	300	0.000136
Ca	75	0.00054
Mg	30	0.00136
Fe	0.3	0.1357
Cr	0.05	0.814
Cl^-	250	0.000163
SO_4^{2-}	200	0.00021
NO_3^-	45	0.00090

1. Weightage

Factors, which have higher permissible limits, are less harmful because they can harm quality of river water, when they are present in very high quantity. Thus, Unit weight (Wi) for various parameters is inversely proportional to its recommended standard value (Vs).

$Wi \ \alpha \ 1/ Vs$

Or $Wi = K/ Vs$

Where, K = constant of proportionality

Σ Wi = 1, considered here

$K= 1/ [(1/ Vs_1)+ (1/ Vs_2)+ ..... +(1/ Vs_n)]$ where n = number of parameters taken for WQI calculation=14

2. Quality Rating

Each chemical factor has been assigned a water quality rating Qi to calculate WQI.

$Qi = 100 [(Va-Vi)/(Vs-Vi)]$ Where,

Va – observed values/concentration of each chemical parameter in each water sample

Vs - standard value of each parameter

Vi - ideal value for pure water (0 for all parameters except pH and DO)

The above equation becomes: $Qi = 100 (Va/Vs)$

For dissolved oxygen (DO): The ideal value = 14.6 mg/l; permissible value = 6 mg/l, $Q_{DO} =100[(Va-14.6)/(6-14.6)]$.

For pH: The ideal value = 7.0; Max. Permissible value = 8.5, $QpH =100[(Va- 7.0)/(8.5-7.0)]$

3. Sub indices $(SI)i = Wi \times Qi$ is to be calculated for each parameter

4. The Water Quality Index Calculation

The resulting sub indices values are added together to arrive at an overall water quality index.

$WQI = \Sigma (SI)i$

Based on the results of physicochemical analysis, irrigation quality parameters like sodium adsorption ratio (SAR), percent sodium (% Na), residual sodium carbonate (RSC) were also calculated (Raghunath, 1987), (Todd, 2006) to assess the suitability of the water bodies for irrigation purposes.

Percent Sodium (Na%)

It is an important parameter to classify the water samples for irrigation purpose which is calculated by the formula in epm,
$Na\ \% = 100\ x(Na^{+} + K^{+}) / (Na^{+} + Ca^{2+} + Mg^{2+} + K^{+})$

Sodium Adsorption Ratio (SAR)

The degree to which the irrigation water tends to enter into cation exchange reaction in soil can be indicated by the sodium adsorption ratio. Since sodium replaces adsorbed calcium and magnesium in soil. Hence it is expressed in epm as
$SAR = Na+ / \sqrt{\{(Ca^{2+} + Mg^{2+})/2\}}$

Residual Sodium Carbonate (RSC)

It refers to the residual alkalinity and is calculated for irrigation water by the following formula.

$RSC = (HCO_3^{-} + CO_3^{--}) - (Ca^{++} + Mg^{++})$ (epm)

RESULTS AND DISCUSSION

The analytical results obtained for various physico-chemical parameters from different sampling locations in the study period are summarized in Table 2 to 4. The pH values varied between 6.06 and 7.43 during the study period. Turbidity ranged from 8.2 to 65.4 NTU. Dissolved oxygen level varied between 4.78 and 8.01 mg/L and BOD ranged from 0.86 to5.16 mg/L. The observed EC values were in the range 96-393 µs/cm. The TDS, TSS and Total Hardness of the water samples varied from 74-247 mgL, 30-168 mg/l and 64-135 mg/l respectively in the study period. Various cations such as Ca^{2+}, Mg^{2+},Na^{+}, K^{+}, Fe and Cr concentrations varied as 12.83-29.74, 0.97-5.83 2.0-13.0, 0.7-3.7, 0.132-1.432 and 0.051-0.194 mg/L respectively. The concentrations of various anions HCO_3^{-}, SO_4^{2-} NO_3^{-}, PO_4^{3-} and Cl^{-} were in the range 41.92-91.46, 2.31-7.16, 0.65-5.30, 0.22-1.18 and 7.41-28.86 mg/L respectively. The total coliform and faecal coliform cells were observed from 970 to 15000 and 70 to 590 CFU/100ml respectively.

Drinking Water Quality

pH

The water samples in study area were slightly acidic to alkaline in pre-monsoon and monsoon periods where as predominantly acidic in post- monsoon period. The minimum value was recorded in post-monsoon and maximum value was recorded during monsoon period. The pH values were within the BIS and WHO limits in almost all stations in the study period except the samples S8 and S12 with below the permissible limit. The recorded high pH values in pre-monsoon may be due to the solar radiation, penetration of water into the soil and high biological activity and the lower value observed during post-monsoon may be due to the influence of fresh water influx, seeping of drainage from mines, low temperature, automobiles and decomposition of organic matter as described by Mandal *et al*. (2012) and Rajathi *et al*. (2013) as well as interaction of water with iron rich laterite, silicate rocks and iron ores (Sahu, P.C. 2003,Unpublished Ph.D. thesis submitted to Sambalpur University, Odisha) which make the water more acidic. The diminished rate of photosynthetic activities reduces the assimilation of carbon dioxide and bicarbonates, which are ultimately responsible for increase in pH (Rajathi *et al*., 2013) in monsoon and pre-monsoon periods.

Turbidity and TSS

The turbidity of surface water is usually between 1 NTU and 5 NTU. Turbidity exceeds both the BIS and WHO standard limits within the study period. Though TSS was within the BIS and WHO limits in some of the stations in pre-monsoon and post-monsoon periods, it was beyond the limits in monsoon period. The water samples were found to be maximum turbid with highest suspended solids during the monsoon and of minimum value in pre-monsoon period, analogous to the results obtained by Mandal *et al*. (2012). This may be due to massive soil erosion, water discharge, urban and rural run- offs, effluents from mines and industries, domestic sewage, recreational use of the streams and river, algal growth, leachates and run off from the overburden dumps as explained by Parmar and Parmar (2010), Rath *et al*. (2010). As per USEPA Guidelines and Rath *et al*. (2010), reduced clarity due to high turbidity and TSS are likely to increase the suspended colloidal particles and contaminate the fresh water sources, often associated with higher levels of disease-causing micro organisms makes the water less desirable for many of its uses. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches. With respect to these parameters the water samples are not suitable for drinking.

EC,TDS,TH

Electrical conductivity (EC) of water is a direct function of total dissolved salts, which is a measure of salinity of water and presence of various cations and anions, minerals and metallic ions comprising both colloidal and dissolved solids as previously reported by Kumar and Dua (2009), Shetty *et al*. (2013). Total hardness in water is mainly imparted by the calcium and magnesium ions, which apart from sulphate, chloride and nitrate are found in combination with carbonates and bicarbonates as explained by Shetty *et al*. (2013), Singh *et al*. (2010). These three parameters are within the permissible limits of BIS and WHO standards. Higher values of EC and TDS were recorded in the water samples of streams in monsoon period and higher values were obtained in post-monsoon period in the water samples of river. Comparatively higher EC values with appreciable level of TDS along with higher TH in some samples like S2,S3,S6,S8,S12 than others, in monsoon and post-monsoon.

Table 3. Physico -Chemical parameters of Local Streams and Baitarani river in Pre- monsoon

sample	pH	Turbidiy NTU	TDS mg/L	TSS mg/L	EC µs/cm	DO mg/L	BOD mg/L	TH mg/L	HCO_3^- mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	PO_4^{3-} mg/L	Cl^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^+ mg/L	K^+ mg/L	total coli CFU/100ml	feacal coli CFU/100ml	Fe mg/L	Cr mg/L
S1	7.1	8.2	74	30	96	7.84	1.02	64	41.92	2.40	1.22	0.35	9.43	14.83	1.58	2.0	1.5	970	80	0.192	0.058
S2	6.97	15.8	141	106	182	6.15	3.25	76	64.38	6.34	3.49	0.47	18.15	19.24	3.16	9.9	2.2	2000	200	0.831	0.125
S3	7.5	13.5	167	65	216	7.65	2.39	104	79.80	5.52	1.03	0.59	16.27	26.25	2.19	7.0	1.8	3750	210	0.502	0.086
S4	7.21	17.3	108	51	137	6.84	1.62	88	56.44	3.41	0.92	0.25	10.92	21.64	3.48	4.0	1.4	3000	150	0.247	0.067
S5	7.40	20.5	153	92	206	5.82	2.09	79	74.31	5.14	0.83	0.28	15.08	18.64	3.89	9.2	2.1	2500	180	0.551	0.124
S6	7.35	15.1	160	85	243	7.46	1.23	80	65.18	2.65	1.91	0.43	12.07	20.86	2.50	4.6	1.1	3000	120	0.626	0.103
S7	6.73	10.4	97	52	120	8.01	0.86	71	55.40	3.65	0.81	0.35	7.87	16.51	2.61	4.3	0.7	2000	70	0.218	0.051
S8	6.35	24.5	178	121	318	4.78	4.23	121	79.94	6.87	4.86	0.48	27.26	27.25	4.38	9.2	1.4	8000	360	1.084	0.172
S9	6.85	17.7	120	63	187	7.04	2.64	82	62.11	5.67	2.29	0.73	13.86	19.04	3.93	5.2	0.9	2500	150	0.445	0.095
S10	7.12	25.2	131	80	223	7.15	1.25	91	69.92	4.66	1.64	0.44	13.68	23.77	1.93	5.7	2.6	3000	220	0.423	0.101
S11	7.06	21.3	115	87	192	7.22	1.17	77	64.73	5.81	1.32	1.01	15.07	20.42	3.98	7.5	2.7	5500	180	0.526	0.118
S12	6.76	23.6	153	106	232	6.71	2.46	108	70.90	4.71	2.85	0.73	28.18	26.13	2.75	8.6	1.6	7000	280	0.587	0.129
S13	7.08	14.3	162	91	217	7.16	1.93	117	87.55	5.38	3.41	1.04	21.98	28.72	4.63	10.1	3.2	6000	200	0.388	0.108

Table 4. Physico -Chemical parameters of Local Streams and Baitarani river in monsoon

sample	pH	Turbidiy NTU	TDS mg/L	TSS mg/L	EC µs/cm	DO mg/L	BOD mg/L	TH mg/L	HCO_3^- mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	PO_4^{3-} mg/L	Cl^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^+ mg/L	K^+ mg/L	total coli CFU/100ml	feacal coli CFU/100ml	Fe mg/L	Cr mg/L
S1	7.26	27.3	98	85	108	7.57	2.63	78	52.17	3.21	1.31	0.22	7.41	17.45	1.59	2.9	1.4	4000	150	0.171	0.062
S2	6.92	53.8	178	151	205	6.07	4.36	86	58.08	5.19	2.92	0.60	14.85	16.05	3.10	9.6	3.4	10000	500	0.512	0.103
S3	7.43	47.6	202	112	287	7.12	2.01	98	70.41	4.02	2.23	0.61	16.77	23.25	1.59	8.3	2.3	8000	300	0.243	0.081
S4	7.10	35.2	121	98	173	6.31	3.17	71	62.72	2.98	1.67	0.32	9.29	20.26	0.97	4.7	1.8	6000	270	0.194	0.075
S5	7.31	48.7	174	134	276	6.65	3.78	74	59.98	4.20	3.64	0.65	11.32	15.03	4.13	6.9	1.5	10500	480	0.317	0.120
S6	7.12	32.2	171	107	294	6.84	2.66	64	63.94	2.26	2.32	0.42	9.54	13.97	3.88	6.6	2.8	8500	270	0.425	0.088
S7	6.51	18.7	103	86	143	7.51	1.05	70	53.02	3.23	1.74	0.35	7.30	12.83	4.38	3.9	1.4	3000	160	0.211	0.053
S8	6.44	65.4	218	168	372	5.87	5.16	108	45.83	4.90	5.30	0.96	17.51	19.26	5.11	10.7	1.8	15000	590	0.658	0.194
S9	7.03	36.3	126	121	176	7.25	2.73	79	61.01	2.93	4.84	0.43	16.13	17.03	4.53	8.8	1.2	8600	350	0.213	0.092
S10	6.86	28.7	108	103	262	7.22	3.38	84	47.23	2.81	3.76	0.51	10.43	14.61	3.16	4.4	2.3	9000	320	0.304	0.125
S11	7.03	39.8	136	125	214	7.46	2.14	80	59.12	4.66	3.74	1.18	13.58	15.63	3.38	7.7	2.7	9000	400	0.291	0.107
S12	6.68	45.1	185	146	271	7.01	4.23	112	68.21	4.37	5.21	0.75	18.96	19.10	3.76	9.5	1.9	11000	520	0.483	0.145
S13	7.01	36.3	208	127	302	7.87	2.85	119	74.31	3.27	4.05	0.96	22.12	25.35	4.04	6.8	3.7	8500	340	0.252	0.119

Table 5. Physico -Chemical parameters of Local Streams and Baitarani river in post- monsoon

sample	pH	Turbidity NTU	TDS mg/L	TSS mg/L	EC µs/cm	DO mg/L	BOD mg/L	TH mg/L	HCO_3^- mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	PO_4^{3-} mg/L	Cl^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^+ mg/L	K^+ mg/L	total coliform CFU/100ml	feacal coliform CFU/100ml	Fe mg/L	Cr mg/L
S1	6.93	14.1	106	103	138	7.16	3.14	85	59.91	3.07	0.93	0.31	10.59	14.35	4.66	3.6	2.0	6000	200	0.132	0.072
S2	6.57	28.3	164	113	285	5.83	4.13	97	61.56	7.16	2.48	0.67	27.15	22.04	5.83	13.3	1.9	7000	350	0.437	0.115
S3	7.16	17.5	182	89	305	6.41	2.65	105	81.21	4.90	3.66	0.66	19.21	27.25	3.16	9.5	1.6	3050	140	0.380	0.095
S4	6.83	15.6	100	64	146	7.04	2.06	71	56.50	3.02	0.65	0.32	13.74	18.04	2.36	6.2	1.3	4000	180	0.358	0.103
S5	6.62	22.1	209	115	315	6.33	3.81	108	62.48	4.59	1.27	0.65	16.32	18.84	3.89	6.8	1.1	4600	370	0.408	0.142
S6	6.87	16.4	236	82	342	7.21	2.05	93	64.98	2.31	0.83	0.45	13.90	20.88	3.32	5.2	0.8	3000	200	0.672	0.114
S7	7.02	11.8	97	43	121	7.69	0.88	77	63.51	2.69	0.73	0.48	8.72	14.03	4.21	6.2	1.4	2500	90	0.265	0.062
S8	6.06	38.7	247	127	393	5.03	4.54	135	84.54	6.63	2.84	0.66	26.05	24.87	5.59	11.9	2.2	11000	510	1.432	0.146
S9	7.20	17.5	131	70	206	7.23	1.13	88	72.97	3.05	1.85	0.82	15.81	20.04	4.81	7.3	1.6	4700	150	0.411	0.107
S10	6.81	19.6	165	83	269	7.61	2.03	78	65.59	3.77	1.98	0.97	12.76	16.33	3.62	8.0	2.7	5000	180	0.367	0.101
S11	6.78	15.4	176	92	285	7.01	1.17	83	55.64	3.38	1.63	1.09	17.81	17.65	2.60	9.0	2.9	4000	140	0.486	0.117
S12	6.26	26.2	212	108	307	7.07	3.11	104	87.00	5.38	3.35	0.92	22.65	23.45	5.58	11.9	2.5	4000	260	0.460	0.153
S13	6.85	17.6	201	102	288	7.30	1.24	130	91.46	6.10	4.15	1.17	28.86	29.74	5.47	13.0	2.9	5000	150	0.384	0.128

Table 6. Classification of irrigation water quality on the basis of TDS,SAR,RSC and Sodium %

TDS		SAR	
Value	Water Quality	Value	Water Quality
<200	Low salinity	0-10	Excellent
200-500	Medium salinity	10-18	Good
500-1500	High salinity	18-26	Fair
>1500	Very high salinity	>26	Unsuitable
RSC (epm)		Na%	
Value	Water Quality	Value	Water Quality
<1.25	Safe/good	<20	Excellent
1.25–2.50	Marginal/doubtful	20–40	Good
>2.50	Unsuitable	40–60	Permissible
		60–80	Doubtful
		>80	Unsuitable

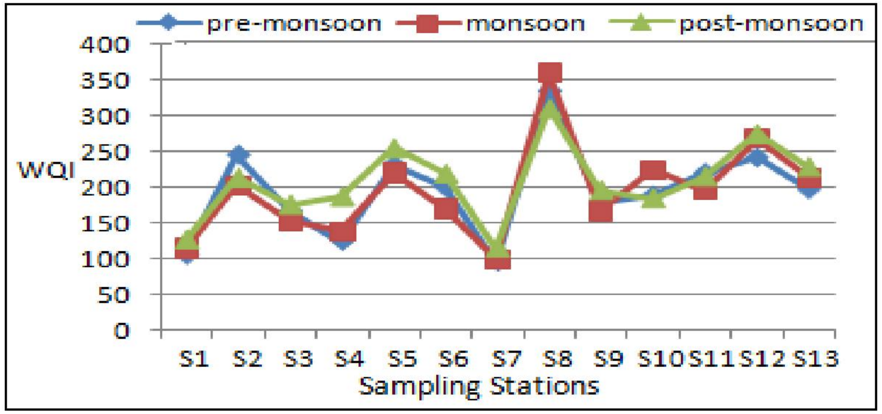

Fig.2. WQI(Water Quality Index) of sampling stations in pre-monsoon, monsoon and post-monsoon periods

These observations are similar to those of Shetty *et al*. (2013). This may be due to multiple factors like weathering of rocks and minerals, the adverse effect of mining with high levels of suspended solids and dissolved solids along with heavy metals, (Rath *et al*., 2010), discharge of sewage from nearby market places and residential areas, agricultural runoff and anthropogenic activities (Singh *et al*., 2010; (Kalavathy *et al*., 2011; Rajathi *et al*., 2013). In the present study, the water samples are of moderately hard category as explained by Muniyan and Ambedkar (2011) and Ravikumar *et al*. (2013).

DO, BOD and Coliform counts

Though DO values are >6, and within limits of BIS and WHO in water samples at most of the stations, the values are not so higher value to consider water quality to be excellent type. The detected DO values of samples S2,S8 are below the the BIS and WHO limits. BOD values in some stations like S2,S5,S8,S10 and S12 are beyond the permissible limits. Maximum DO and BOD values were recorded in monsoon period where as minimum DO and BOD values were observed in pre-monsoon and post-monsoon period respectively for the analysed samples. It is largely attributed to increase in aeration level due to fresh water influx in monsoon with increased flow current of river water. Similar observation was also found by Singh *et al*. (2013). Faecal coliforms originate in human and animal waste. Total coliforms include faecal and also other bacteria with similar properties which originate in soil and are non faecal. Much higher number of total coliform and faecal coliform cell units were found throughout the study period. Maximum units of coliform cells were detected during monsoon period than the respective levels in Pre- monsoon and Post- monsoon.

Higher coliform population during monsoon is due to increased land run off and higher faecal inputs into the river and streams from various sources is similar to earlier findings of Rath *et al*. (2010), Srivastava and Srivastava (2011). Minimum units of coliform cells were detected in water samples of river and streams in post- monsoon and pre-monsoon period respectively. This scenario of coliform bacteria indicates microbial contamination thereby lowering the DO levels and raising BOD values of the water samples at some stations, particularly S2,S5,S6,S8,S12, as described by Mukherjee *et al*. (2012) and are risk to human health as per BIS, WHO guidelines. Thus, the water samples are not potable. Some stations like S2,S5,S8, S12 are also not suitable for beneficial uses, particularly in monsoon, as per the descriptions of Mukherjee *et al*. (2012), Shukla *et al*. (2011). Coliform bacteria may not cause disease, but used as one of the indicators of pathogenic contamination with the risk of water-borne diseases such as intestinal infections, dysentery, hepatitis, typhoid fever, cholera and other illnesses (Srivastava and Srivastava, 2011). The common practice of the people living along the streams and river catchment area to discharge their domestic and agricultural waste into the river, using the river water for bathing, washing, open defecation and urination etc.by human being also by wild and domestic animals, untreated sewage disposal storm runoff, etc. are the causes of coliform bacteria in the water body.

Cations and Anions

Variation of concentrations of various cations and anions like Ca^{2+},Mg^{2+},Na^{+},K^{+},HCO_3^-,NO_3^-,SO_4^{2-},PO_4^{3-} and Cl^- of the water samples in different periods were not in a particular trend. Most of the samples were of higher concentrations of these ions in post-monsoon period than those of pre- monsoon and monsoon period where as in some samples higher concentrations were recorded in pre-monsoon period. NO_3^- concentration was recorded to be higher in monsoon period than the other periods. All these parameters were well within the BIS and WHO limits throughout the study period. Higher concentrations of these ions in pre -monsoon period is because of semi arid type of climate and low flow condition which promotes higher rate of evaporation causing increase in concentration of ions where as lower concentrations in post monsoon is due to recharge of water body and dilution factor as effect of the monsoon (Dash *et al*., 2014). Higher values of the parameters in post-monsoon period is the effect of monsoon such as influx of various eroded materials from mine sites, villages, market areas and agricultural fields along with soil erosion, weathering of rocks, atmospheric precipitations and anthropogenic activities like sewage disposal as well as recreational use of the streams and river. Similar results were presented by Prasath *et al*. (2013), Mandal *et al*. (2012), Singh *et al*. (2010). Generally Ca^{2+} in water is derived from minerals like limestone and dolomite and lithological calcareous constituents and the sources of Mg^{2+} are basic igneous rocks such as amphibolites; volcanic rocks such as basalts, metamorphic rocks such as talc and tremolite–schists; and sedimentary rocks such as dolomite. Olivine, augite, biotite, hornblende, serpentine and talc are some major magnesium-bearing minerals (Dubey *et al*., 2014).

Presence of Ca^{2+} and Mg^{2+} may also be due to the seepage of effluent and domestic wastes or cationic exchange with Na^+ (Kalavathy *et al*., 2011). However, the low concentrations of Ca and Mg do not mean that they are not influenced by the pollutants but it might be due to the reverse cationic exchange with Na^+ which was previously explained by Prasath *et al*. (2013). In the study area, the degree of variation of Na content is probably due to the differential weathering of the plagioclase feldspar of the parent rocks, domestic sewage and wastes as well as the base exchange of Ca and Mg. (Karanth, 1987). Minerals like orthoclase, microline, and muscovite are responsible for the K content in the water of the study area, the range of which is relatively low, because of its resistance towards dissolution and its adherence to clay minerals (Dash *et al*., 2014). Higher concentrations of sulphates, nitrates, chlorides and phosphates in water samples near to more populated and mines areas S2,S4,S5,S6,S8 may be due to mining and industrial discharges, presence of sodium and calcium chloride in natural water and high salinity, sewage and garbage disposal, fertilizers, decayed vegetables and animal matter and recreational use of water bodies (Kalavathy *et al*., 2011), (Abir, 2014), (Singh *et al*., 2010). The secondary source of sulphate may be weathering of traces of pyrites associated with iron minerals.

Fe and Cr

The concentrations of Fe and Cr in the water samples show that most of the samples were of high metal contents in all seasons exceeding BIS limits. Fe in some stations is below the WHO limit. Higher concentrations of dissolved metals in pre-monsoon periods than that of monsoon and post-monsoon periods indicate the accumulation of the metals during low flow condition of the river. It may be attributed to high evaporation rate of surface water, followed by elevated temperature as described by Abdel (2001). According to Pandey (2009), in some cases, high concentration in post-monsoon period was due to effect of rain such as dissolution of rocks and minerals, run offs from mine sites, agricultural fields and urban as well as rural areas and atmospheric precipitation. The high concentrations of iron is due to runoff of iron- rich soil and mining activities of iron ore mines close to the streams (USEPA, 1994) as well as the leachates and run off from the overburden dumps (Rath *et al*., 2010). The observed high value of Cr in water may be due to physical and chemical weathering of rocks and soil, anthropogenic sources including mining, industrial, domestic waste and sewage effluents originating from nearby urban and rural areas draining and leaching into the river (Akhionbare, 2011)

Irrigation water Quality

The suitability of the water samples were assessed on the basis of classification of irrigation water with respect to TDS,SAR,RSC and Sodium % (Table 6) according to Richards (1954), Wilcox (1995), Ravikumar *et al*. (2013), Sahu, P.C. (2003 Unpublished Ph.D. thesis submitted to Sambalpur University, Odisha). The calculated irrigation quality indices (Table 7) indicated that all the samples in pre-monsoon period and 77% in monsoon and 61.5% in post-monsoon period are of low salinity category. 23% of samples in monsoon and 38.5% of sample in post-monsoon are of medium salinity. All the samples in the study period have SAR 0-10 and RSC less than 1.25. Considering the Na%, 54% samples in pre-monsoon 31% in monsoon and 15.4% in post-monsoon are of excellent quality. 46% of samples in pre-monsoon, 69% in monsoon and 84.6% of samples in post-monsoon period are of good quality for irrigation purpose. Thus, the overall assessment is that the water samples are safe and good for irrigation purpose.

Table 7. SAR, Na% and RSC values of water samples in pre-monsoon, monsoon and post-monsoon periods

Samples	Pre-monsoon			Monsoon			Post monsoon		
	SAR	Na%	RSC	SAR	Na%	RSC	SAR	Na%	RSC
S1	0.129	12.387	-0.183	0.181	14.139	-0.147	0.212	15.914	-0.117
S2	0.552	28.488	-0.162	0.575	32.308	-0.104	0.653	28.447	-0.571
S3	0.352	18.978	-0.182	0.451	24.583	-0.137	0.460	21.924	-0.289
S4	0.212	13.325	-0.441	0.278	18.767	-0.063	0.365	21.689	-0.168
S5	0.505	26.557	-0.032	0.406	23.669	-0.107	0.373	20.461	-0.236
S6	0.253	15.458	-0.177	0.400	25.948	0.032	0.277	15.434	-0.250
S7	0.257	16.412	-0.131	0.158	12.877	-0.131	0.373	22.690	-0.005
S8	0.433	20.260	-0.409	0.560	26.970	-0.613	0.562	25.198	-0.315
S9	0.285	16.470	-0.255	0.490	25.290	-0.223	0.379	20.365	-0.200
S10	0.302	18.927	-0.199	0.273	20.231	-0.215	0.465	26.680	-0.038
S11	0.400	22.821	-0.285	0.461	27.584	-0.089	0.528	29.704	-0.183
S12	0.429	21.418	-0.368	0.522	26.841	-0.144	0.572	26.290	-0.203
S13	0.461	22.313	-0.379	0.316	19.113	-0.379	0.577	24.893	-0.435

WQI

The water quality index does not show exact degree of pollution, rather it is used to assess water quality trends for the management purpose (Mukherjee *et al*., 2012). The WQI results represent the level of water quality in a given water basin. The computed WQI values are classified into five types, namely, excellent water (WQI<50), good water (50>WQ<100), poor water (100>WQI<200), very poor water (200>WQI<300) and water unsuitable for drinking (WQI>300).as described by Ravikumar (2013), Mukherjee *et al*. (2012) and Dubey *et al*. (2014). It was observed that WQI values ranged from 96 to 359 (Fig.2).

Only 7.7% of sample are of good quality in pre-monsoon period and none of the sample is under these category in pre and post-monsoon period. 54 % of the samples in pre-monsoon, 61% of the samples in monsoon and 46% of the samples in post-monsoon are of poor quality. 31% of the samples in pre-monsoon and monsoon, 46% in post monsoon are of very poor quality. 7.7% of the samples are in each of the pre-monsoon, monsoon and post-monsoon periods are considered to be unsuitable for drinking. It clearly shows that none of the sampling stations have excellent water quality, indicating lack of access to safe potable water supply.

Conclusion

On the basis of the present study of various physico-chemical parameters, it was found that though the cations and anions along with pH are within the BIS and WHO standard limits for almost all samples of the local streams and Baitarani river, none of the samples is fit for direct human consumption with respect to water quality index. Maximum sampling stations are contaminated with high total coliform including faecal coliform bacteria. Water is slightly acidic at some stations, particularly in post-monsoon period and alkaline in most of the stations in monsoon and pre-monsoon period. Comparatively low DO and high BOD values along with high turbidity and TSS, high values of Fe and Cr indicate poor quality of water. In the present study, WQI reveals that degradation of water quality is due to high concentrations of Fe and Cr. None of the water samples was of excellent quality. Overall assessment is that almost all of the samples are poor to very poor quality. BOD, TSS, turbidity and coliform counts (CFU/100ml) as well as iron and chromium are relatively higher in local streams than that of Baitarani river. This may be due to low volume of water, low flow condition, dense population in the catchment area and flowing of streams in the close proximity of various iron and manganese mines. The sources of contamination are domestic sewage, disposal of garbage, soil erosion, mines run off and anthropogenic activities with extensive recreational use of the streams and the river. The sample S8 is of the most unsuitable with respect to WQI as well as other parameters because of anthropogenic activities through more population and presence of iron and manganese mines very close to the stream. Also, water samples at other stations such as S2,S5,S6,S12 are of very poor quality. The overall study of water quality clearly indicates that the water sources of the study area cannot be used for public consumption without any treatment though all samples are of good quality for irrigation purpose on the basis of TDS,SAR,RSC and Sodium% values. Lack of sanitary awareness mostly open defecation among the local people is one of the most important factors for the degradation of water quality in this area. Therefore, there is a need for proper management to check the disposal of wastes into the streams and river/river catchment and to control and monitor human activities along with public awareness to ensure its minimal negative effect on the water body. Deforestation should be strictly enforced to check the massive soil erosion. The present baseline information of the physico-chemical parameters of water samples would form a useful tool for further ecological and environmental assessment and monitoring of these water ecosystems, leading to the safe survival of the inhabitants in the study area.

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